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PROBLEMS FOR RADIATION PROTECTION SPECIALISTS IN SAFETY EVALUATIONS

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DISCLAIMER

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INTRODUCTION

Radiation Protection Specialists are charged with the protection of man and his environment from unwarranted radiation exposure while working to attain maximum benefits to mankind from the proper use of radiation. The beneficial use of radiation is important to mankind; for example, radionuclides are used in medicine for both diagnositc and treatment purposes when no other agent can produce the helpful results. X-rays are used not only for medical purposes but also for industrial applications to provide a better and safer life for all. The role of nuclear reactors in power generation for the coming decades appears assured although a considerable effort in radiation safety evaluations may be required to convince the public that this program can be safely administered.

Like all chemicals, radiation in excessive amounts can produce damage in living organisms. It is the role of the Radiation Protection Specialist to prescribe control methods and techniques to assure that no significant damage occurs from the beneficial use of radiation. Radiation Protection Specialists face complex situations daily requiring careful planning to avoid radiation problems. For any particular facility the size of the effort required for radiation protection may vary from a part-time assignment of a single individual to a complete organization with many specialists attending to specific areas of the radiation protection program.

The areas of radiation protection that may be faced by Radiation Protection Specialists include Radiation Monitoring and Surveillance, Personnel Dosimetry, Radiation Standards, Radiological Design Principles, Nuclear Safety, Nuclear Material Management, Environmental Evaluations and Radiological Emergencies.

In facing these areas, the proper role of the Radiation Protection Specialist is anticipating and solving problems relating to how to accomplish radiation work safely. He has done his job well when "no problems" occur. With proper planning, cooperation, adequate knowledge and management support the Radiation Protection Specialist can assure the safe use of radiation.

RADIATION MONITORING AND SURVEILLANCE

First to be considered in designing radiation protection programs is the identification of radionuclides and the quantities to be handled. Obviously, small quantities of short half-life (few day) radionuclides are much less problem than large quantities of long-lived (years) radionuclides. Each encounter requires the right level of radiation protection control measures. The Radiation Protection Specialist needs to plan his program of problem solving to be sure external radiation exposure, contamination spread, and internal deposition of radioactive materials are properly controlled. Basically, this goal is accomplished by thorough training of the individual performing the radiation work and by providing adequate work facilities.

Training should be directed at emphasizing the use of shielding, controlled work durations, distance, and remote or semi-remote handling for materials that present external radiation hazard and contamination control by the use of hoods or glove boxes and proper operational methods for uncontained radioactive materials. Good techniques were established with the development of the atomic age to make possible now the use of safe work practices. It is a matter of adequate radiation protection specialist training and knowledge, staff training and knowledge, and funds to design, build and operate the radiation facility properly.

One should recognize immediately that facilities designed for the proper handling of radionuclides will be more expensive and more complex in design than many other industrial facilities. A relatively small expenditure can buy a sufficient quantity of radionuclides to require a facility and control procedures costing millions of times the radionuclide purchase price. One needs to remain alert to be sure the facilities are adequate for the work to be performed.

Radiation Protection Specialists need good instrumentation to provide the dose and contamination detection measurements required. The monitoring instrumentation needs to respond to radiation types, energies and radioactive quantities encountered. These instruments should be convenient to use, dependable in operation and suitable for proper calibration and rapid interpretation.

A good practice to develop in avoiding problems is the adoption of written procedures detailing how specific radiation work will be accomplished. One such procedure, perhaps referred to as a "Radiation Work Procedure," should detail the radionuclides involved, the protective equipment required, and the special care or handling methods to be used. The procedures should be read, understood and approved by both the Radiation Protection Specialist and the group or individual performing the radiation work. Each individual performing work authorized by the Radiation Work Procedure needs to fully understand its conditions and requirements.

Any facility routinely handling radioactive materials should receive periodic radiation surveys to assure the control over the radioactive materials is adequate. Such surveys should be scheduled, completed and reviewed on a frequency that will provide good surveillance. Air samples may also be required to determine air quality in the working areas. Most any work with radioactive materials will require shipping and receiving of radioactive packages and proper packaging and monitoring should be assured to result in safe transport of materials. More than likely some radioactive waste products will be generated during the work and an appropriate waste disposal program that assures radionuclides do not enter the environment in quantities or concentrations greater than approved levels needs to be in place.

In addition to the routine and daily work program, radiation monitoring teams or individuals need to be ready to respond to radiation emergencies. Appropriate instrumentation and procedures should be in place to minimize the consequences to the staff and the environment of any loss of control over radioactive material.

PERSONNEL DOSIMETRY

The Radiation Protection Specialist needs to know the types and exposure conditions that will be encountered so that appropriate personnel dosimeters can be used. Frequently, personnel dosimeters may be available from commercial firms providing this service. Initially in most countries it is necessary for those first working with radioactive materials to design and have manufactured their own dosimeters. Basically, personnel dosimeters need to meet the following general specifications:

1. Provide a linear dose response with energy over a wide dose range.

2. Cover the dose range from essentially zero to the maximum that might be encountered in a serious

accident---perhaps several hundred rads.

3. Be able to differentiate between penetrating and nonpenetrating radiation. Normally the ability to penetrate to a depth of 5 grams per square centimeter of tissue equivalent material is used to define penetrating radiation.

4. Be stable for the period during which they are used without fading or dose enhancement occurring.

5. Be calibrated at all energies and dose levels that may be encountered.

6. If neutrons will be encountered, specific read-out and calibration for neutron exposure should be provided.

A radiation exposure record system should be established to maintain the record of not only personnel dose results but also radiation incidences, contamination occurrences, and all abnormal events involving radiation that are encountered by each staff member. The records of instrument and dosimeter calibrations procedures and results should be maintained.

A quality control auditing system to evaluate dosimeter performance and evaluation is recommended. Equipment and methods for performing bioassay analysis or invivo measurements should be available. The relatively complex methods for evaluating the results of these programs should be thoroughly understood and carefully practiced if meaningful results are to be attained.

RADIATION STANDARDS

All radiation protection programs should be designed to maintain radiation exposure at the lowest practicable levels. The specific radiation standards to be used for controlling both external exposure and internal deposition should be identified. Normally, such standards follow closely the recommendations of the International Commission on Radiological Protection (ICRP). A country may wish to adopt more restrictive standards than these in some areas, but one should think through very seriously the wisdom for adopting standards in excess of those proposed by ICRP or other authoritative groups within a country. Standards for concentrations of radionuclides in the air and water should also be identified and monitoring programs should be established to see that they are met.

RADIOLOGICAL DESIGN PRINCIPLES

Radiation protection is achieved through physical protective features supplemented by administrative controls. The Radiation Protection Specialist should be directly involved in the design and operation of facilities provided for work with radiation. Adequate physical protective features should be achieved in building construction so that supplemental administrative controls may be kept simple and workable. A building designed with adequate physical protective features should result in substantial operating economics resulting from the ease and efficiency of maintaining sound radiation protection practices throughout the useful life of the building.

The intended use of a building, and therefore, the kinds and quantities of radioactive materials employed, may change even before the building is completed. It is common for a building which was designed with a minimum of physical protective features to be used for projects which require greatly increased emphasis on radiological safety. Within the limits of good judgment, the building should be designed for operations involving larger quantities of materials of higher radiotoxicity than initially proposed.

One of the underlying concepts in the control of radioactive materials and radiation is the use of a buffer zone between active work areas and areas which are free of radiation and radioactive materials. This intermediate area may be as small as an air lock or it may encompass a major part of the building. A buffer zone serves to minimize the consequences of occasional loss of control in the active work area by providing a second barrier. A third barrier is sometimes used for operations involving a high potential for loss of control, particularly where the consequences of such loss would be serious. The outer barrier should be needed only as a consequence of a failure of the inner barrier.

Radiological design criteria enumerate the basic design features and requirements of facilities for safe work with radioactive materials or radiation generating machines. Shielding and physical protective features should be included which will facilitate operations and keep exposure of persons to radiation and radioactive materials as low as technically and economically feasible (as low as practicable). Collectively, the building features and operating procedures should (1) keep planned exposures to radiation workers within prescribed limits and as low as practicable, (2) keep casual exposure of persons not engaged in radiation work low to avoid unwarranted use of exposure that may be need for radiation work, (3) keep exposure or the threat of exposure to persons not controlled as near zero as possible, and (4) maintain control in spite of operational failures or facilitate recovery of control when operational procedures fail.

Appendix A gives in considerable detail Radiological Design Criteria that may be considered in providing new facilities or in modifying existing facilities. Not every item in the suggested criteria is mandatory - but every item should be reviewed for applicability to the facility being considered.

A. General Building Considerations

The location of each new building or radiation laboratory room should be chosen so that radiological hazards to the surrounding facilities and environs will be minimized. If the movement of radioactive material to and from a building interferes with normal operations in adjoining rooms or buildings, annoying, impractical and imposing controls could be necessary. For example, an unfavorable location for waste disposal will lead to increased waste treatment costs, tank storage requirements, or transport to more favorable disposal sites.

Radiological problems within a well designed building should be decreased by providing permanent shielding for some operations, by providing for the future use of temporary shielding and casks, by design for traffic control and location of various operations to minimize interference, and by design for air flow which will minimize contamination spread. One-story construction has the advantage of avoiding possible interferences, both above and below. Hazards involved in spills, breaking of process lines, contamination control, fire fighting, and cask handling favor ground floor location for Radiation Zones.

The goal of building traffic control should be to limit access to sources of ionizing radiation and contamination. Three building zones (Radiation Zone, Controlled Zone and Uncontrolled Zone) should be utilized in building design to achieve this goal.

Good traffic control design should minimize radiation exposure subsequent to a contamination spread, criticality or fire. The extensive use of air locks at all exits including emergency exits as a means of contamination control should be considered. Provision should be made for isolated and locked areas that prevent unnecessary or inadvertent entry to areas where high radiation dose rates or large amounts of radioactive materials may be encountered. Consideration should be given to the ease of decontaminating work stations and to provisions for decontaminating equipment. The maintenance of a building and equipment may necessitate the design of special maintenance facilities.

All facilities in which radioactive materials or radiation generating machines are used should include provisions for adequate posting of radiation warning signs. Consideration should be given to the desirability for building radiation monitoring systems and a centralized read-out of the systems. The absolute prevention of all personnel contamination cannot be assured; hence, facilities for personnel decontamination should be provided.

B. Ventilation

The ventilation system (supply and exhaust) of a radiological facility supplements the facility layout in controlling the movement of radioactive materials from contaminated areas toward uncontaminated areas. The ventilation rate is usually controlled by this function, and is therefore usually higher than needed solely for the comfort of the workers. Freedom from dust should be assured. The design should avoid drafts and eddies, which tend to spread contamination. It is usually desirable to design for direct smooth downflow of air across the working faces of glove boxes or hoods, so that in the event of a glove puncture or other damage, any contamination which may escape is carried away from the workers' faces and localized near the affected hood. The goal of the exhaust air treatment should be to keep the release of radioactive material to the environment to a minimum.

C. Water Supply and Sewer Systems

Design of water supply and sewer systems needs to prevent accidental contamination of supply systems and should ensure disposal of aqueous waste into the proper sewer and prevent disposal of waste materials to an improper sewer. Design should consider the following types of waste separately: (1) sanitary sewage, (2) process waste water not threatened with radioactive contamination, (3) waste water which normally meets the previous classification but which might contain radioactive material because of failure of equipment or personnel error and (4) waste water which normally contains radioactive material. The design should also provide for the disposal of liquid wastes which are not acceptable in any of the waste water systems - oil, for example.

D. Radioactive Work Stations

The control of radioactive materials to prevent their becoming a source of internal exposure can be made easier by design and selection of proper equipment for laboratories. Because of the small quantities which are considered significant, high radiotoxicity materials may create a major problem if they are mismanaged; the risk of significant exposure may be great. Work stations for manipulations with low radiotoxicity materials should be remote from work stations where high radiotoxicity materials are to be employed.

Shielding should be determined by the nature of the work. Shielding may be provided by the construction of massive structures or the use of water-filled basins. Consideration should be given to preventing the accidental loss of water in the construction of a basin.

The shielding and safety requirements for any radiation generating machine or large radioactive source dictates the need for obtaining the services of a qualified expert early in the planning stage. Information should be provided on the type of installation, rating of the machine or source, the contemplated use of the x-ray, the expected workload and use factors, the structural details of the building and the type of occupancy of all areas which might be affected by the installation.

E. Radiation Monitoring Systems

Several systems are employed to insure continuous control of radiation exposures. Administrative procedures, employment of personnel whose job is administration of radiation protection services, use of personnel dosimeters, use of fixed and portable instruments for measurement of dose rates, and measurement of radioactivity in effluents and wastes are some of the more obvious devices employed. Fixed radiation monitoring devices are provided to assure continuous knowledge of ambient penetrating radiation dose rates and to signal significant changes in those dose rates. High radiation level and criticiality alarms are provided to insure evacuation of personnel from locations where dangerous levels of radiation could possibly occur. Criticality dosimeters provide a measurement of doses which might otherwise be difficult or impossible to obtain. Air samplers provide an after-the-fact measurement of airborne radioactive materials, and air monitoring instruments provide occupants immediate warning of significant changes. Portable detection instruments and fixed personnel check stations provide a means of detecting personnel contamination. Air balance and locked doors are

are devices used to control spread of contamination and to control movement of personnel. Annunciators and alarms may be required to insure prompt correction of breaches in the control system. Measurement and control of exhaust air and waste water are necessary to insure control of radiation exposures to persons outside of normal control areas.

NUCLEAR SAFETY

When fissionable materials are present in a building in excess of that required for the assembly of one critical mass, a nuclear safety program is required. This program should be designed to provide a double contingency control to prevent a critical occurrence. Consequently, two totally independent errors or equipment failures would be required before a criticality could occur. It is a good practice to require safety hazard analyses, which study in technical depth to analyze the potential accidents that could occur in such a facility and potential consequence of their occurrence. Good performance should be assured by auditing the handling procedures and practices relating to nuclear materials.

Criticality alarms should be provided so that people working in the facility can immediately evacuate if a criticality takes place. Good emergency evacuation procedures known to all in the facility should be in place. Some method of personnel accountability is desirable to assure all people are accounted for following an accident.

NUCLEAR MATERIAL MANAGEMENT

When critical masses of fissionable material are in inventory, it is necessary to keep detailed records of the quantity of material in any given location. One needs to establish inventory records for each work location and provide a double checkoff system when material is added or removed from that work location.

It is appropriate to maintain strict accountability on all fissionable materials to assure that none are lost in the process. Lost materials may be building up in a location and eventually lead to an unexpected criticality event.

ENVIRONMENTAL EVALUATIONS

The environment of a nuclear facility or laboratory should be monitored to determine the impact of the facility. Environmental monitoring programs may be quite elementary if a small quantity of only a single isotope is involved, or may be indeed complex if a large operation with large quantities of many isotopes are involved.

Typical environmental measurements would include:

1. Air concentrations of radioactive materials throughout the region.

2. Concentrations of radioactive materials in streams, rivers, and lakes in the region.

3. Special samples of underground water supplies and wells to determine possible leakage into these systems.

4. Samples of various foods should be analyzed for radionuclide content.

Particular attention should be given to possible reconcentration that may occur particularly by marine organisms.

Study may be necessary to identify pathways of radionuclides through the environment to man or animals.

In all of these programs it is desirable to develop methodology to calculate the dose to humans from the concentration of radionuclides found in the environment. All dose calculations should be compared with radiological standards to make an assessment of the true impact on the environment of the radiation work.

RADIOLOGICAL EMERGENCY

Although every precaution should be taken in designing and working with radioactive materials, it is also prudent to be prepared for accidents. One should examine the materials in inventory and assess the potential impact from all reasonably conceivable accidents. It is a good practice to prepare a Safety Analysis Report (SAR) for any major program. The SAR should consider all potential accidents, their consequences in view of the protective features included in the facility design and operating methods and assess the impact of the accident on the environment and staff. After study of the SAR, a judgment should be made relative to whether it is appropriate to proceed with the work or not.

Attention should be given to preparing emergency plans to quickly assess the potential of an abnormal occurrence and for recovering from the accident. Emergency guidance and special instrumentation are usually desirable to meet these needs. Aerial survey methods can quickly give general areas of concern for ground survey. Communication with field monitoring teams during emergency surveys may be most critical. Portable radio equipment is helpful to obtain quick radiation survey results and to direct emergency team efforts to areas of most concern. A capability in the field of meteorology is desirable to provide quick estimates of potential atmospheric dilution and to obtain guidance on the direction of travel for any airborne release. Practice sessions and special training in meeting emergency conditions should be held.

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APPENDIX A

RADIOLOGICAL DESIGN CRITERIA

The following Radiological Design Criteria should form the basis for a good, practical and safe facility for working with radioactive materials. While not every item is to be considered as mandatory--each item should be considered for applicability. Items should not be discarded because they may be expensive--but only when it is clear from the nature of the work to be performed that they are not necessary. These radiological design criteria have been tested by actual use with highly favorable results.

Radiological Guides

1. Classification of Building Zones

   A. Radiation Zone

      - Any location where the combination of anticipated dose rate and anticipated occupancy indicates a dose to persons exceeding 20 mrem per week.

      - Any location where the anticipated dose rate exceeds 2 mrem/hr.

      - Any location containing unconfined radioactive materials.

      - Any location where the concentration of airborne radioactive materials may exceed occupational Maximum Permissible Concentrations (MPC's) prescribed by ICRP or the IAEA or other authoritative group for occupationally exposed groups.

B. Controlled Zone

- Any location where the anticipated dose rate exceeds 0.2 mrem/hr but does not exceed 2 mrem/hr and where the combination of anticipated dose rate and anticipated dose rate and anticipated occupancy indicates a dose to persons less than 20 mrem/week.

- Any location where unconfined radioactive materials may be expected occasionally because of operational failure, equipment failure, or routine maintenance.

- Any location where the concentration of airborne radioactive materials may exceed nonoccupational MPC's.

C. Uncontrolled Zone

- Any location where no radiological control activities are required.

2. Exposure of Penetrating Radiation

- All persons shall be restrained from receiving radiation exposure at a rate exceeding 1000 mrem/hr by shielding or locked physical barriers.

- In Radiation Zones where radiation exposure is a necessary part of the work being performed, shielding shall be provided where the anticipated annual dose exceeds 1000 mrem. When shielding is provided, it shall reduce the anticipated annual dose to 1000 mrem or less. If annual occupancy time cannot be estimated, then shielding shall reduce the weekly dose to 20 mrem. If no information on occupancy time is available, shielding shall reduce the dose rate to 0.5 mrem/hr.

- In Controlled Zones and in Radiation Zones where radiation exposure is not a necessary part of the work being performed, shielding shall be provided to limit the anticipated annual dose to occupants to less than 1000 mrem. If the annual occupancy time cannot be estimated, then shielding shall reduce the dose rate to 20 mrem/week or 0.5 mrem/hr. However, the dose rate in a Controlled Zone shall not exceed 2 mrem/hr.

- In Uncontrolled Zones shielding shall be provided, as necessary, to reduce the dose rate to 0.2 mrem/hr or less. In addition, where persons outside direct control may be exposed, shielding or a fence shall be provided to insure against such persons receiving an annual dose exceeding 170 mrem.

3. <u>Exposure to Radioactive Contamination</u>

- Radioactive contamination on surfaces outside Radiation Zones shall not exceed 2000 d/m per cm^2 ($\sim$ 10 pCi/cm^2) for beta-gamma emitters nor 500 d/m per 100 cm^2 ($\sim$ 2 pCi/cm^2) for alpha emitters.

- The annual average concentration of airborne radioactive materials within Radiation Zones at all locations normally accessible to personnel shall not exceed one-tenth of the occupational Maximum Permissible Concentrations (MPC's).

- All persons shall be restrained by physical barriers, locks or interlocks from entering areas where concentrations of airborne radioactive materials exceeding 10 times the occupational MPC's are anticipated.

- Persons in Controlled Zones or Uncontrolled Zones shall not be exposed to concentrations of radioactive materials in air or water exceeding the nonoccupational Maximum Permissible Concentrations.

4. Classification of Radioactive Materials

High Radiotoxicity Materials

Beta Emitters	Alpha Emitters	
^{90}Sr	^{210}Po	^{241}Am
^{210}Pb	^{223}Ra	^{243}Am
^{227}Ac	^{224}Ra	^{242}Cm
^{228}Ra	^{226}Ra	^{243}Cm
^{230}Pa	^{227}Th	^{244}Cm
^{241}Pu	^{228}Th	^{245}Cm
^{242m}Am	^{230}Th	^{246}Cm
^{249}Bk	^{231}Pa	^{248}Cm
^{253}Cf	^{230}U	^{249}Cf
^{254}Es	^{232}U	^{250}Cf
^{255}Es	^{238}Pu	^{251}Cf
	^{239}Pu	^{252}Cf
	^{240}Pu	^{254}Cf
		^{253}Es

Low Radiotoxicity

Noble Gases, Uranium, Natural Thorium and other radioculides having a specific activity less than 1×10^{-6} curies per gram.

Medium Radiotoxicity

All other radionuclides.

5. Classification of Work Stations

Areas shall be designated as Class A, B or C Work Stations, depending on the form, quantity, and radiotoxicity of the unconfined radioactive material to be used. Table I shall be used to determine the classification to be applied to the work station.

A work station where only sealed sources are used shall be classified as Class C.

Readily Dispersible as used in Table I shall include radioactive materials in the form of gases, aerosols or powders, pyrophoric radioactive materials or radioactive materials associated with combustibles.

Dispersibles as used in Table I shall include radioactive materials in the form of unsealed non-combustibles, liquids and solids.

TABLE I

CLASS OF WORK STATION

Form → / Quantity ↓	Hi Radiotoxicity: Readily Dispersible	Hi Radiotoxicity: Dispersible	Med Radiotoxicity: Readily Dispersible	Med Radiotoxicity: Dispersible	Low Radiotoxicity: Readily Dispersible	Low Radiotoxicity: Dispersible
above 1 Ci	Class A Work Station	Class A Work Station	Class A Work Station	Class A Work Station	Class B Work Station	Class C Work Station
1 Ci – 1 mCi	Class A Work Station	Class A Work Station	Class A Work Station	Class B Work Station	Class B Work Station	Class C Work Station
1 mCi – 1 μCi	Class A Work Station	Class B Work Station	Class B Work Station	Class B Work Station	Class C Work Station	Class C Work Station
1 μCi – 1 nCi	Class B Work Station	Class B Work Station	Class C Work Station	Class C Work Station	Class C Work Station	Class C Work Station
below 1 nCi	Class C Work Station	Class C Work Station	Class C Work Station	Class C Work Station	Class C Work Station	Class C Work Station

General Building Considerations

1. Site Considerations

   A. New buildings shall be located so that normal operations, including anticipated minor accidents, do not adversely affect surrounding buildings, and conversely, so that normal operations in surrounding buildings do not adversely affect the new building.

   - Dose rates outside a building shall not exceed the guides listed for Controlled Zones. In an area where dose rates exceed 0.2 mrem/hr, provision shall be made (a fence) to prevent the general public or any person whose exposure is not being controlled from receiving dose in excess of 170 mrem in a year.

   - No facilities for handling uncontained radioactive material out-of-doors shall be permitted.

   - Operations that are sensitive to radiation (counting rooms, photographic operations, etc.) should be isolated from and shielded from facilities and operations which produce significant dose rates.

   B. Buildings requiring the routine movement of high dose rate materials which require heavy shielding should be served by a railroad spur.

2. <u>Stacks</u>

Stacks shall be at least 20 feet higher than the roof of the facility, and shall be located at least 20 feet down wind (refer to windrose for facility location) from the air intake of the facility or at least 500 feet upwind from the air intake of an existing facility.

The height and location of a stack serving some facilities may have overriding requirements based on a specific accident analysis.

3. <u>Structure</u>

- A one-story building shall be considered. If overriding considerations dictate the need for a multi-story building every effort shall be made to locate all radioactive work stations on the ground or first floor.

- Heavy duty floors shall be provided to accommodate problems which may result from the transporting of casks or installation of heavy shielding.

- High ceilings should be avoided where readily dispersible radioactive materials will be used.

4. <u>Building Zones</u>

A. A building shall be divided into three zones: Radiation Zone, Controlled Zone and Uncontrolled Zone. Normal access from areas outside the building to a Radiation Zone shall be through a Controlled Zone and a physical barrier or check point (e.g., a door or receptionist) shall be located at the point where the Controlled Zone can be entered from an Uncontrolled Zone or from out-of-doors. Exists from Radiation Zones directly to the outside shall be installed only where required as emergency exits. Specific items pertaining to each of the building zones are as follows:

- <u>Radiation Zone</u>

  This category shall include all rooms and areas in which radioactive materials are stored, handled, or processed. Rooms falling into this category shall be confined to one area of the building.

- <u>Controlled Zone</u>

  Zones that are normally free of contamination but which have a potential for becoming contaminated shall be included in this category. Change rooms and related facilities should be located in this Zone.

- <u>Uncontrolled Zone</u>

  No radioactive materials will be permitted, therefore, no radiological considerations will be necessary.

B. In addition to the provision of facilities for storing and dispensing clean clothing, the change room shall contain a defined area near the point of exit from the Controlled Zone for the temporary storage of potentially contaminated used clothing.

C. Provision shall also be made for storage of radiation monitoring survey instruments to be used for personal survey or release of material from the Controlled Zone.

5. <u>Traffic Flow and Air Locks</u>

The normal flow of traffic shall be restricted to the Uncontrolled Zone or Controlled Zone. Normal traffic patterns shall not include Radiation Zones. Areas of high potential for either contamination or radiation shall be located outside the normal flow of traffic. Air locks shall be incorporated at any exit from a high contamination area direct to an Uncontrolled Zone.

6. <u>Decontamination and Maintenance</u>

A. Future decontamination requirements shall be considered in the design of hoods, cells, glove boxes, and process equipment. Rough surfaces, square corners, cracks or crevices, and absorbent materials shall be avoided. Disposable linings, covers, coatings, or easily decontaminated surfaces shall be utilized.

B. Walls and ceilings in Class A or B work stations shall be nonporous and washable. Paints used to cover these surfaces shall be of a quality that retains its original covering properties when subjected to repetitive washing with common detergents.

C. Class A or B work station floors shall be covered with individual tiles.

D. A separate decontamination and maintenance facility shall be provided for any building containing more than ten Class A or B work stations. These facilities shall be considered work stations and equipped as required in criteria for work stations. In addition, the following should be considered in designing the decontamination and maintenance facility:

- Remote visual inspection of radioactive components.
- Handling and transfer of major components.
- Physical separation of major activities such as decontamination, remote maintenance, contact maintenance and storage.

E. Consideration should be given to the provision of a utility corridor which would aid in maintenance of utilities and removal of solid radioactive wastes.

7. <u>Radiation Protection Specialist Lab-Office</u>

A. Each building containing Class A or B work stations shall have at least a lab-office combination to accommodate one radiation protection specialist.

B. For large facilities, the radiation protection specialist lab-office shall be designed to accommodate additional personnel:

Class A Work Station

Two monitors for the first 30 radiation workers plus one additional monitor for every 30 additional radiation workers.

Class B Work Station

Two monitors for the first 50 radiation workers plus one additional monitor per additional 50 radiation workers.

Class C Work Station

One monitor under some circumstances.

C. Each lab-office shall include a minimum of six lineal feet of lab lench, 12 lineal feet of open shelving, and one regulated voltage electrical outlet for every two feet of bench space. Two lineal feet of lab bench and four lineal feet of open shelving shall be added to above requirements for each additional radiation monitor provided for.

D. The radiation protection specialist lab-office shall be located at or near the exit from the Controlled Zone.

E. A readout from building monitoring systems should be provided in the radiation protection specialist lab-office.

8. Work Station Monitoring Facilities

- Each work station in which radioactive material or a radiation generating machine is to be used shall have a bench or shelf approximately two square feet in area located at the opening side of the door for portable or semi-portable survey instruments.

- An electrical outlet shall be located at the bench or shelf.

- A suitably sized bulletin board shall be located above the bench or table for posting procedures and instructions.

9. Dosimeter Storage

- Storage racks shall be provided for the radiation worker's dosimeters where special dosimeters are required.

10. Posting

- Fixed brackets shall be provided at each door to a Controlled Zone or Radiation Zone to attach an appropriate radiation warning sign. The sign shall be located to the right of the door and about five feet off the floor.

11. Personnel Decontamination

- A personnel decontamination room shall be located near the change rooms or rest rooms in any facility containing Class A or B work stations in which unsealed radioactive materials are used.

- Equipment in the personnel decontamination room shall include a telephone, a work bench, an examination chair, a sink and shower connected to a monitored sewer system and a storage cabinet for decontamination supplies.

12. Breathing Air Supply System

Design of facilities should include centralized breathing air when several work stations require the occasional use of a special breathing air supply for personnel protection and when a few work stations require the use of fresh air for personnel protection for periods of several hours at a time. Special breathing air supply equipment is required under the following conditions:

- When gaseous radioactive materials in an occupied area may be expected to exceed occupational MPC's.

- When airborne particulate radioactive material in occupied areas may be expected to exceed 20 times the occupational MPC's.

- When high radiotoxicity materials are being handled outside enclosures such as hoods, glove boxes and cells in amounts exceeding 1 μCi and in a form (powder, solution, friable solids, etc.) which might readily produce airborne contamination.

- When maintenance or decontamination may require personnel entry into cells, or other areas where large amounts of loose radioactive material may be encountered.

When a breathing air system is provided, it shall meet applicable safety standards, which specify hose coupling and manifold design. Air supplied shall be free of oil, water and dust. Hose couplings should be provided with a plastic cover to prevent contamination from entering the system. The proposed work load will determine the number of hose couplings which should be provided at each station, but stations shall be provided near the normal entryway. In determining the location of stations, consideration should be given to the length of hose required to reach a work location. Long hoses tend to become tangled and contribute to the spread of contamination. Stations should be outside of highly contaminated areas to reduce the problems of hose coupling contamination and to facilitate "suiting up".

13. Material Transfer Systems

Material transfer systems, such as tanks and pipe lines for radioactive fluids and casks for solids or liquids, require many design considerations. In addition to other design problems, consideration should be given to radioactive contamination control and control of radiation exposure during the transfer of process materials or maintenance of equipment. Remote handling, valving and instrument readout should be designed for work operations involving high dose rates, high contamination levels and high radiotoxicity materials. Consideration should be given to the use of overhead lifting equipment such as cranes and monorails in preference to wheeled carts and carrying vehicles. Pipe lines used for transfer of radioactive materials should operate under vacuum. The design needs to include filtration and proper disposal of waste water from jets and off-gases from the vacuum system. Filters and scrubbers should be used to protect the vacuum pump from contamination. Welded connections are preferred to screwed couplings. A double barrier (e.g., pipe inside a pipe) should be provided when it is necessary for a transfer line to pass through normal work areas; shielding may also be rquired. Design dose rates are discussed in another section. Fluid transfer facilities should be designed to provide positive protection against backup in valve actuating lines or instrument sensing lines. They should also be designed so that lines drain completely and to prevent inadvertent pressurization and filling of a portion of the line. Transfer systems should be designed for easy flushing and internal cleaning. Particular attention should be given to the control of radioactive materials which might be spread when temporary connections are broken. Pressurized transfer systems are to be avoided; however, when it is necessary to design a pressurized system, extreme care should be used in design to assure control of radioactive materials from leaks and at points where connections may be broken. An auxiliary protective barrier should be provided for all such systems.

Design features for the movement of solids, casks, bottles, and boxes should make it convenient to keep the outside surface free of radioactive contamination. Transfer of materials into and out of a radioactively contaminated area should be designed to take place through an air lock. This not only reduces the transfer of contamination with the parcel, but also reduces the disturbance of the air balance necessary to control contamination in the contaminated work zone. Decontamination, wrapping or coating may need to take place in the air lock to assure contamination control.

14. <u>Solid Waste Disposal System</u>

All radioactive wastes are to be buried at approvied disposal sites. The design needs to, therefore, provide for the accumulation, storage and handling of solid wastes compatible with acceptable transportation to disposal sites. Design may need to include design of casks or other special equipment to facilitate handling and transport of solid wastes. Solid wastes may include small volumes of liquids made compatible with solid waste requirements by being packed in or absorbed in an absorbent material. Waste handling equipment may need to include hoists, cranes, remote handling equipment, or packaging facilities. Facilities provided for waste handling need to meet the same criteria for control of radiation exposure and contamination as to all other work stations during storage, transport and disposal. Segregation of non-radioactive and radioactive waste is important to reduce operating costs.

- Design of facilities should provide for segregation of wastes, storage and preparation for transport and burial.

- Waste packages having a dose rate less than 100 mrem/hr at the surface may be handled by routine procedures. Design may need to provide shielding at the storage location.

- Shielded shipping casks should be provided for waste packages having a dose rate greater than 150 mrem/hr at 10 feet.

- The outside surfaces of all waste shipments need to be free of loose contamination. Design should include facilities for packaging and decontamination if these are required.

- Materials which may constitute an explosive or fire hazard need to receive special attention and need to therefore be segregated from radioactive wastes.

Air Supply and Exhaust System

1. Air Supply System

- The air supply rate shall be lower than the exhaust rate in Radiation and Controlled Zones. Exhaust control dampers shall fail to the open position. Supply control dampers shall fail to the closed position.

- Exhaust duct work shall be designed with sufficient stiffeners to withstand the full differential when the supply control dampers fail closed.

- The ventilation rate in Radiation and Controlled Zones where uncontained radioactive materials are handled in hoods shall be 8 to 15 air changes per hour.

- Adequate intake air filters shall be provided to minimize dust in work areas and to reduce dust loading on exhaust filters.

- Air balance shall be designed to assure air movement from non-radioactive areas to moderately or occasionally contaminated zones and then to highly contaminated or high risk zones. Supply fans should automatically cut out when there is insufficient exhaust fan capacity in service. Alarms shall be provided to signal loss of proper air balance.

- Air pressure differentials between uncontaminated and contaminated areas shall be between 1/10 and 1/4 inch of water. Pressure differentials between 1/4 and 1 inch of water shall be maintained between moderately or occasionally contaminated areas and highly contaminated areas (hoods, cells). Air pressure shall be negative with respect to atmosphere in all areas except offices, areas and zones where radioactive materials are not allowed. Normally, air locks should be used to insure maintenance of proper differentials.

- Open faced hoods may have an adjustable front opening. The linear air velocity through the hood opening shall be 150 $\pm$ 25 ft/min. The hood front shall be designed for smooth, eddy free air flow and for protection from back drafts caused by motions of workers and objects in the room.

2. Recirculating Air Systems

- Particular care should be exercised in the design of recirculating air systems for areas where radioactive materials will be handled to insure removal of airborne radioactive materials. The system shall be designed to supply air at concentrations less than nonoccupational MPC's.

- Provision shall be made for sampling recirculated air downstream of fans and filters. Instrumented monitoring with alarms and automatic dampers to supply clean air and exhaust contaminated air shall be provided where concentrations exceeding occupational MPC's might occur.

- Recirculating air sy[illegible] rooms where high radiotoxicity materi[illegible] airborne shall be provided with two hi[illegible] particulate air (HEPA) filter banks in seri[illegible]ch needs to be in the exhaust vent at the [illegible]borne activity might be introduced.

- HEPA and charcoal fi[illegible] tested in place after installation. Samp[illegible]njection nozzles shall be provided fo[illegible]sequent routine testing.

3. Exhaust Air Systems

   A. Auxiliary backup e[illegible]mper controls shall be installed to provid[illegible]flow during shutdown or power failure.

   B. Ducts which may ca[illegible] materials should not pass through Uncont[illegible] Special attention should be given to [illegible] contamination spread from maintenance or [illegible]ations.

   C. Filtration and tre[illegible] designed to ensure that building exhau[illegible]rations will not exceed nonoccupational MPC[illegible]h radiotoxicity materials are being han[illegible]in which they might become airborne, ei[illegible]ely or accidentally, double filtration s[illegible]ed even though a single filter would satisf[illegible]iterion.

D. HEPA Filters shall be used in exhaust systems for restraining particulate material and charcoal filters shall be used in exhaust systems for restraining radioiodine.

E. HEPA (and charcoal, if needed) filters shall be provided in vacuum systems, cells, hoods, glove boxes and room exhausts to provide primary removal near the source, if radioactive materials are to be handled in a way in which they might become airborne, either deliberately or accidentally. Design should make replacement of such filters easy and also facilitate contamination control during replacement, especially when heavy loading with radioactive material is anticipated.

F. Protection of the environment should be maximized by installing HEPA (and charcoal filters, if needed) near the exhaust fans to intercept materials which may have accumulated in the duct work or which may have escaped when upstream filters were being changed or were damaged.

G. HEPA and charcoal filters shall be tested in place after installation. Sample probes and injection nozzles shall be provided in original construction to facilitate this and subsequent routine testing.

Water Supply and Sewer Systems

1. Water Supply Systems

- Sanitary water shall be provided in Radiation Zones only for safety showers and fire protection sprinkler systems. Drinking fountains shall not be located in Radiation Zones. Drinking fountains should be located in Controlled Zones, in change rooms, in personnel decontamination rooms and in corridors where contamination can be controlled except for occasional accidents.

- Process water supplied to radioactive processes and Radiation Zones shall be isolated from sanitary water systems, either by separated system such as a tank and pump or by an approved back flow preventer.

2. Waste Water Sewers

A. General

- Drains, sewers, catch tanks, etc., as required shall be provided to facilitate segregation and continuous control of liquid waste streams, and to simplify sampling, monitoring and diversion. Sinks and drain lines shall be labeled to indicate to which sewer system they are linked.

- Backflow of air through sewer lines shall be prevented by use of seals or suction fans.

- Class A work stations and adjacent areas which might receive the effects of a spill or an accidental release shall be served only by a contaminated sewer or a high level waste tank.

- Gravity flow should be utilized for the transfer of liquid waste.

B. Sanitary Sewers

- Radiation Zones shall not contain sinks equipped with drains connected to a sanitary sewer.

- The discharge of process waste to any sanitary sewer is not permitted by these criteria.

- Sanitary sewer lines should not pass through areas where radioactive contamination is expected.

C. Process Waste Sewer

- Process sewers shall be equipped with a sampling system which provides a representative sample of the waste.

- Process sewers shall not be provided in Class A or Class B work stations or in adjacent areas which might become accidentally contaminated. Particular attention should be paid to floor drains, janitor sinks, process equipment, and personnel decontamination stations which might receive radioactive materials either through normal use or by accident.

D. Retention Sewer

- Cooling water and other normally non-radioactive waste water from Class A or Class B work stations or adjacent areas should be discharged to a retention sewer.

- A monitored waste system with diversion capabilities similar to the retention sewer shall be provided for the disposal of normally non-radioactive waste water from Class A or Class B work stations and adjacent areas which might become accidentally contaminated.

- Connection to the retention sewer or other monitored waste system shall not be provided for the normal disposal of radioactive waste or where accidental release of more than 1 curie of any radionuclide might occur.

E. Contaminated Sewer

- A contaminated waste system shall be provided to receive deliberate disposal of radioactive aqueous wastes in amounts less than 200 curies and wastes from accidental spills, equipment and surface decontamination, and diversion from the monitored waste system when that is required.

- Where a central contaminated sewer system is not provided, facilities shall be provided to adequately handle such wastes as are generated and to preclude inadvertent disposal of contaminated waste to sewer systems not designed for proper control.

- Where a central contaminated sewer system is provided that system shall be discharged to the Contaminated Waste Sewer.

- Fixtures, equipment, and piping used for disposal of radioactive waste shall be of materials that are highly resistant to corrosive agents, including those which may be introduced to the system for decontamination. Stainless steel should be used for piping and equipment; sinks of stainless steel or vitreous china should be used. Stainless steel pipe and fittings shall be welded at all joints. Surfaces of sinks and piping shall be smooth and free of abrupt bends or depressions which may allow accumulation of solids. Where particulate material, such as grindings and cuttings may be encountered, the waste water shall be filtered before it enters the contaminated waste system.

- Waste flow from source or origin to the storage or disposal location shall be by gravity. The consequences of contamination spread shall be evaluated by competent radiation protection personnel before committing the design of a radioactive waste system to the use of positive pressures in excess of 10 ft of water. The high cost of pump maintenance in high dose rate areas should also be considered.

- Contaminated waste lines should not pass through areas within a building which are not planned to be Radiation Zones.

- Normal maintenance points such as cleanouts should be designed and located with contamination control in mind. Ease of maintenance should be considered in designing a contaminated waste system.

3. <u>High Level Wastes</u>

- Special tanks or other system shall be provided for the disposal of quantities of radioactive materials exceeding 200 curies.

- A vacuum system (jets may be used) shall be provided to raise wastes with high dose rates into shielded casks for transport. In no case shall such liquid streams be put under positive pressure.

- Underground pits containing waste storage tanks shall be equipped with sumps containing alarm monitors to indicate leaks or spills. Such sumps and high level systems shall not be connected to any other waste system.

Radioactive Work Stations

1. Class A Work Stations

- Class A work stations shall be located inside a Radiation Zone.

- Materials of construction shall be corrosion resistant and incombustible.

- Work stations shall be equipped with a closed hood or cell.

- Supply air to a hood or cell shall be filtered through a high efficiency particulate air (HEPA) filter for positive prevention of spread of contamination.

- Exhaust air shall be filtered in the hood or cell.

- Work stations shall be equipped with contaminated sewer connections.

- Provision shall be made for the temporary storage of solid waste at each work station.

- All piping, valve stems, drive shafts, etc., shall have an air tight entrance through a rigid (metal or concrete) portion of the hood or cell. Back flow of radioactive materials into piping shall be prevented.

- Insertion and removal of materials through bags or sphincters shall be preferred. Air locks may be used if necessary, but are considered less desirable.

- If hood gloves are provided, double ring seals shall be required. All equipment should be within easy reach of gloves.

- Motors, pumps, valves, etc., shall be contained in cabinets which are easy to decontaminate.

- Series of hoods should be compartmentalized into several small areas so that a contamination spread is confined to a small area.

2. <u>Class B Work Stations</u>

- Class B work stations shall be located inside a Radiation Zone.

- Materials of construction should be corrosion resistant and incombustible.

- Work station shall be equipped with, at least, an open faced hood.

- Waste water lines shall be routed to a sewer designed to accept radioactive waste in the quantities anticipated.

3. <u>Class C Work Stations</u>

- Class C work station need not be located inside a Radiation Zone. However, radioactive material shall be located within a Radiation Zone which, in this case, may constitute only a part of the work station.

- Air exhaust near the work station shall be adequate to maintain concentrations of radioactive materials in breathing zones below occupational MPC's.

- Exhaust air shall be filtered.

- Waste water shall be routed to a sewer designed to accept radioactive waste in the quantities anticipated.

4. <u>Storage Facilities</u>

- Plans for storage of more than 300 Ci of radioactive material at a concentration exceeding 100 μCi/g shall be reviewed by the radiation protection specialist.

- High radiotoxicity materials shall be stored in containers or facilities providing at least two barriers to prevent the loss of control of material. The barriers shall be designed to provide containment at all times when the material is in transit or stored outside a suitable work station as described above.

- Medium radiotoxicity materials shall be stored in containers or facilities presenting at least one barrier to loss of control of the material. The barrier shall be designed to provide containment at all times when the material is in transit or stored outside a suitable work station as described above.

- Separate storage facilities shall be provided for all Class A work stations where more than 300 Ci of material will accumulate, and for storage of casks or other transfer vessels used outside the work stations. Storage facilities for contaminated tools and equipment should be provided if such facilities will aid in keeping work stations uncluttered.

5. <u>Storage of Sealed Sources</u>

- Encapsulated (sealed) sources shall be shielded as necessary to insure that no person is subjected to more than 0.2 mrem/hr in routinely occupied locations. Unauthorized access to shielded sources shall be prevented. Consideration should be given to detection and control of radioactive material in case of failure of encapsulation.

- The source storage enclosure should be located near the point of use to reduce the exposure of personnel during transfer of sources.

- Separate compartments should be provided for different types of sources. The shielding provided by the individual compartments and the enclosure as a whole should minimize the dose rate to a person standing in front of the enclosure.

6. Shielded Work Stations

- Shielded work stations shall meet the radiological criteria for a Controlled Zone, as well as other criteria pertaining to Class A, B or C work stations which apply if the radioactive material is not contained within the shield.

- Water-filled canals, pools or pits may be used for handling or storage. Radioactive materials handled or stored this way shall be limited to insoluble solids or encapsulated items. Accidental siphoning or emptying of water shall be prevented. Accidental exposure to underwater items by removal of materials from the water shall be prevented by appropriate physical restraints. Basins and similar facilities should be lined or painted to facilitate decontamination. The water should be circulated through filters and ion exchange beds for decontamination and water clarity.

7. Radiation Generating Machines and Large Source Installations

- Design of facilities for the use of radiation generating machines, particle accelerators, or large sources shall be reviewed by the Radiation Protection Specialist.

Radiation Monitoring Systems

1. Central Monitoring Panel

- A building containing Class A or B work stations shall be supplied with a central monitoring panel for meters, recorders and annunciators.

- A central read-out panel for automatic monitoring instrumentation should be provided in the Radiation Protection Specialist office.

2. Remote Area Monitoring

- Remote area radiation monitoring systems shall be provided for any area where dose rates to personnel in excess of 250 mrem/hr may occur.

- High level alarms shall be provided for any area where doses to personnel in excess of 10 rem may be possible.

- The remote area monitoring system shall meet performance criteria established by the radiation protection specialist.

- Automatic dose rate alarms shall be provided at routinely occupied work locations and shall be adjustable to alarm over the range of the detectors.

- The radiation monitoring system shall indicate the radiation dose rate from remote stations on a read-out panel in the Radiation Protection Specialist office.

- The range of the radiation detectors should be 1 mR/hr to 10^4 R/hr.

- The remote detectors shall be interchangeable and have in-place calibration capability.

- Self-checking failure alarms should be provided on all channels of the system.

- Continucus recorders should be provided when in the opinion of operating management, radiation exposure control would be improved.

3. Criticality Alarm System

- Any building where more than one critical mass of fissionable material is permitted to be present shall have a criticality detector and alarm system.

- The criticality alarm system shall include neutron detectors, an annunciator comparator unit, fail-safe relay control unit, isolated and filtered power, and howlers.

- The criticality alarm system shall be connected to a continuously occupied location.

- There shall be a minimum of three detectors in a system, with two detectors within 300 feet of any fissionable materials with no more than the equivalent of one foot of intervening concrete. Material-detector distances shall be reduced to accommodate thicker shields.

- Changes in specifications, locations, etc., of criticality detectors and alarm system components, shall be reviewed by the radiation protection specialist.

4. Criticality Dosimeter

- The Criticality Dosimeters shall be located to provide the necessary personnel dose interpretation capability if an accident should occur.

5. Room Air Sampler

- Fixed air sampling facilities shall be provided in all rooms, work areas, laboratories, and operating areas which are to be used as Class A or B work stations.

- Sample heads shall be placed at selected locations, either representative of the breathing zone of the worker or indicative of room air contamination. To be representative the sampler head should be located above floor level within a three-foot radius of the work locations. To be indicative the sampler head should be located in front of the room air exhaust. The minimum installation frequency shall be one sample head per room, area, etc.

- Areas occupied by personnel where concentrations of airborne radionuclides are expected to exceed occupational MPC's shall contain a sensitive automatic alarming device which shall alarm when the airborne concentration equals or exceeds 10 occupational MPC's; the maximum allowable interval for the alarm to respond shall be less than two hours.

- Fixed room air samplers may be operated by vacuum furnished from a central vacuum system or by individual samplers. The capacity of the vacuum system shall be capable of providing a pressure drop equal to twenty inches of water at each sampling head when all sampling heads in the system are in simultaneous use.

- The central air sample vacuum system shall be separate from the vacuum system maintained for other facility services.

6. Building Air Balance Alarms

- Appropriate annunciators shall be provided to signal the loss of building air balance. These shall alarm in a continuously occupied location.

7. Door Alarms

- Except for the main entrance, annunciators should be provided on all doors leading to the outside of building containing Class A and Class B work stations.

Annunciators shall signal the fact that doors are open and that a breach in the contamination control system exists. These shall alarm at a central panel which may be in the Radiation Protection Specialist office or a central control room.

8. Exhaust Air Monitoring

- Provision shall be made to sample air in all vents and stacks exhausting air from areas which include Class A, B or C work stations.

- Continuous air monitoring instruments shall be installed where releases exceed nonoccupational MPC's may occur as a result of an accident.

- A sampling probe shall be installed where continuous sampling is required. The sampler nozzle shall be positioned parallel to the axis of the stack with its open end pointed upstream. The access port through which the sampling probe is inserted shall be equipped to permit cross-duct sampling during initial operation to permit permanent positioning of the nozzle in the optimum location relative to the centerline of the stack. The probe nozzle and sample line shall be sized with reference to the sample size required to attain an air velocity into the probe nozzle approximately the same as in the stack (isokinetic flow).

- The sampling probe shall be located where a reasonable degree of mixing can be expected to occur. Normally, this shall be at least six diameters beyond the last bend or confluence.

- Exhaust air ducts from Class A or B work stations shall have sampling points provided in which sampling probes as described above may be inserted subsequent to building construction.

- Probes shall be provided both upstream and downstream of each filter or scrubber to permit routine sampling and testing of efficiency. HEPA filters shall be subjected to a DOP test after installation to check for leaks. Necessary equipment shall be provided to permit the routine measurement of pressure drop across filter banks. Readout and alarm from a continuously monitored location shall be provided at the Radiation Monitoring office or central control room.

- Exhaust air samplers may be operated from a centralized vacuum system or by an independent motorized pump at the sampling locations. A pressure drop of twenty inches of water shall be required at each sampler. Exhaust air from a stack or duct air sample vacuum system shall be returned to the exhaust plenum via a closed system.

9. Liquid Waste Monitoring

- Provision shall be made for sampling all waste streams except sanitary sewers from a building containing Class A, B or C work stations.

- If the process sewer system is connected to a retention waste system, the monitoring and diversion provisions of the retention waste system shall be considered adequate to satisfy the sampling and monitoring requirements.

- Monitoring and diversion of wastes to storage or to a suitable sewer shall be provided where there is a significant probability that accidental release of radioactive materials may exceed occupational liquid effluent concentration guides.

- Waste monitoring systems provided for a facility shall readout and alarm in the Radiation Protection Specialist office.